Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

aS21
.A75453
Cop.3

S

A PNEUMATIC SYSTEM FOR HANDLING WASTES FROM A POULTRY-PROCESSING PLANT

ARS-S-134
August 1976

RECORDS

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

	Page
Abstract	1
Introduction	1
Experimental procedures	2
Equipment requirements	2
Equipment installation	2
Results	7
Conveying tubes	8
Pollution abatement	9
Water-use reduction	9
Maintenance	10
Literature cited	10

ILLUSTRATIONS

Fig.		
1.	Layout of pneumatic waste-handling system	3
2.	Separator and discharge rotary valve	4
3.	Separator and discharge rotary-valve assembly	4
4.	Collection hopper and rotary valve for heads	5
5.	Typical hopper, rotary valve, and conveying-transition arrangement	5
6.	Collection hopper and rotary valve for feet	5
7.	Diverter valve used to switch airflow from eviscerating line 1 to line 2	5
8.	Collection hopper for oil sacs	6
9.	Orthographic views of an oil-sac hopper	6
10.	Isometric view of an intestinal-tract hopper	6
11.	Inside of an intestinal-tract hopper showing openings to allow flush water to drain	7
12.	Isometric view of a modified intestinal-tract hopper	7
13.	Collection hopper for crops and windpipes	7
14.	Modified crop and windpipe hopper	8
15.	Warning-system circuit	8

TABLE

1.	Comparative waste loads of two eviscerating troughs: a conventional system and a pneumatic waste-hauling system	9

A PNEUMATIC SYSTEM FOR HANDLING WASTES FROM A POULTRY-PROCESSING PLANT

By W. K. Whitehead, R. E. Childs, and E. J. Lloyd[1]

ABSTRACT

A pneumatic waste-handling system was designed, installed, and evaluated in a commercial poultry-processing plant. The system effectively collected and transported the waste materials (heads, feet, and viscera) from the processing area and substantially reduced the pollution entering the plant effluent. Overall plant effluent was reduced by: BOD_5 (biochemical oxygen demand), 28%; suspended solids, 25%; and fat, 75%. Removal of the waste products by means of pneumatic tubes, rather than by floating these materials out in a stream of water, helped to reduce the water requirements of the processing plant by 23%. **KEY WORDS: pneumatic waste handling, poultry, poultry-plant engineering, poultry processing, waste, waste disposal, water-pollution control.**

INTRODUCTION

More than 3 billion head of poultry were slaughtered under Federal inspection in the United States in 1973 (*8*).[2] Kerns and Holemo reported that processing plants in Georgia used an average of 10.7 gal of water per bird for slaughter, evisceration, and further processing (*6*). They also showed that for plants serviced from municipal supplies the average cost for water was $0.45/1,000 gal.

Raw waste loads in effluents discharged by poultry-processing plants are tremendous. Woodard et al. reported that waste loads per 1,000 broilers were: BOD_5 (biochemical oxygen demand), 39.6 lb; suspended solids, 33.5 lb; and fat 22.8 lb (*10*). Carawan et al. reported that BOD_5 loads ranged from 25 to 45 lb/1,000 birds for one processing plant (*3*).

Until the passage of antipollution laws, most poultry processors were not concerned about water use or pollution in their effluents. Water has been plentiful and cheap in most processing areas, and effluents have been discharged into streams or municipal sewers at low or no cost to the processor. Now, because of mandatory restraints and ordinances by city, State, and Federal agencies, processors are faced with ultimatums to reduce or eliminate raw waste in effluents prior to discharge. Also, the cost of potable water continues to rise, making conservation economically important.

One cause of excess water use and high waste-loads in effluents is the common practice of fluming waste materials (heads, feet, feathers, viscera, and other inedible parts) from the plant in a stream of water. The eviscerating area, a primary contributor to the waste load, accounts for about one-third of the total waste and water use in some processing plants (*10*). Continuous-flow hand-washing facilities in the eviscerating area require as much as 3.5 gal/min per station (*3*). In almost every processing plant more water than necessary is used for cleaning and for the fluming of waste products from the plant.

Many methods have been suggested to reduce plant requirements for potable water. High-pressure spray nozzles for flushing the sides

[1] Agricultural engineer, industrial engineer, and engineering technician, Richard B. Russell Agricultural Research Center, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 5677, Athens, Ga. 30604.

[2] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

of the eviscerating trough at timed intervals, rather than a continuous flushing, can save 0.38 gal/bird (*3*). The reuse of chiller water in the scald tank can save up to 0.25 gal/bird (*7*). Whitehead et al. described a final bird washer that reduced water use as much as 1 gal/bird (*9*). These and other practices can reduce water requirements substantially, but they do nothing to reduce the loading of raw waste into the effluent. For this problem, the best solution would be to prevent waste material from entering the water stream.

The objectives of this study were to develop alternative methods of handling waste materials to reduce pollution and to reduce the amount of potable water required to process poultry. A pneumatic waste-handling system was designed, installed, and evaluated in a commercial poultry-processing plant.

EXPERIMENTAL PROCEDURES

Equipment Requirements

In a waste-handling system, air may be used as the conveying medium for any suitable material (*5*). Such a system has three basic components: a fan or blower, a feeder, and a separator. The fan or blower accelerates and lifts the material in the connecting pipes. The feeders may be rotary valves, screw conveyors, or simple duct openings. The separator operates as a cyclone to remove the material from the airstream and then discharge it.

Pneumatic systems may operate on either positive or negative pressure, depending on the relative locations of the blower, the feeders, and the separator. Negative-pressure systems, with the blower located downstream from the separator, offer several advantages for the removal of processing wastes: (1) blowback at the feeder is prevented since leakage is inward, (2) feeder arrangements are simple, and (3) branch circuits can have pickup stations at several locations.

An air system requires properly sized ducts to connect the three main components, hoppers to catch the material for the feeders, and controls and warning devices for breakdown or other malfunctions. Air velocities above 5,000 ft/min are needed to convey materials with bulk weights above 25 lb/ft^3 (*2*). Poultry waste (heads, feet, and viscera) weighs approximately 35 lb/ft^3. Air velocity and duct size determine the size of the fan or blower. Fan horsepower is determined from (1) the capacity required (ft^3/min); (2) pressure losses resulting from airflow in the duct, at entries and exits, and in the separator; and (3) the energy necessary to accelerate and lift the material and to overcome friction.

Ducts of various sizes may be used, but only one size will give the most economical system. Each material has a minimum transport velocity, and the amount of air varies directly with the cross-sectional area of the duct. The combination of waste materials and the operational conditions under which analysis must be made make it hard to establish design specifications. Much of the information established in this study was determined by trial and error.

Equipment Installation

A negative-pressure pneumatic waste-handling system was designed and installed at a commercial poultry-processing plant to remove all processing wastes except blood and feathers. The system was installed in sections so that the effectiveness of various components could be evaluated and to avoid undue interruption of daily plant operation.

The processing plant had two defeathering lines with a total capacity of 9,600 birds/h for 16 h/day. Two eviscerating troughs were used, with one-half the production passing over each trough. The complete installation (fig. 1) handled the heads, feet, and viscera (oil sacs, intestinal tracts, and crops and windpipes) from all poultry processed (9,600 birds/h). At this rate, the system as installed handled a waste load of: heads, 16 lb/min; feet, 22 lb/min; intestinal tracts, oil sacs, and crops and windpipes, 50 lb/min.

Air flows continuously through the conveying tubes at high velocity, entering the ducts through orifices in the hoppers in the eviscerating room. During normal operation, pressure at the pump was about 8 inHg vacuum.

The system was installed in three phases. The first installation handled only the heads and feet; the second added the oil sacs, intestinal tracts, and crops and windpipes from one eviscerating line (4,800 birds/h), and the final step was to collect and handle the wastes from the second line.

Vacuum pump.—The vacuum pump is rated at 1,000 ft^3/min at a vacuum of 18 inHg and is

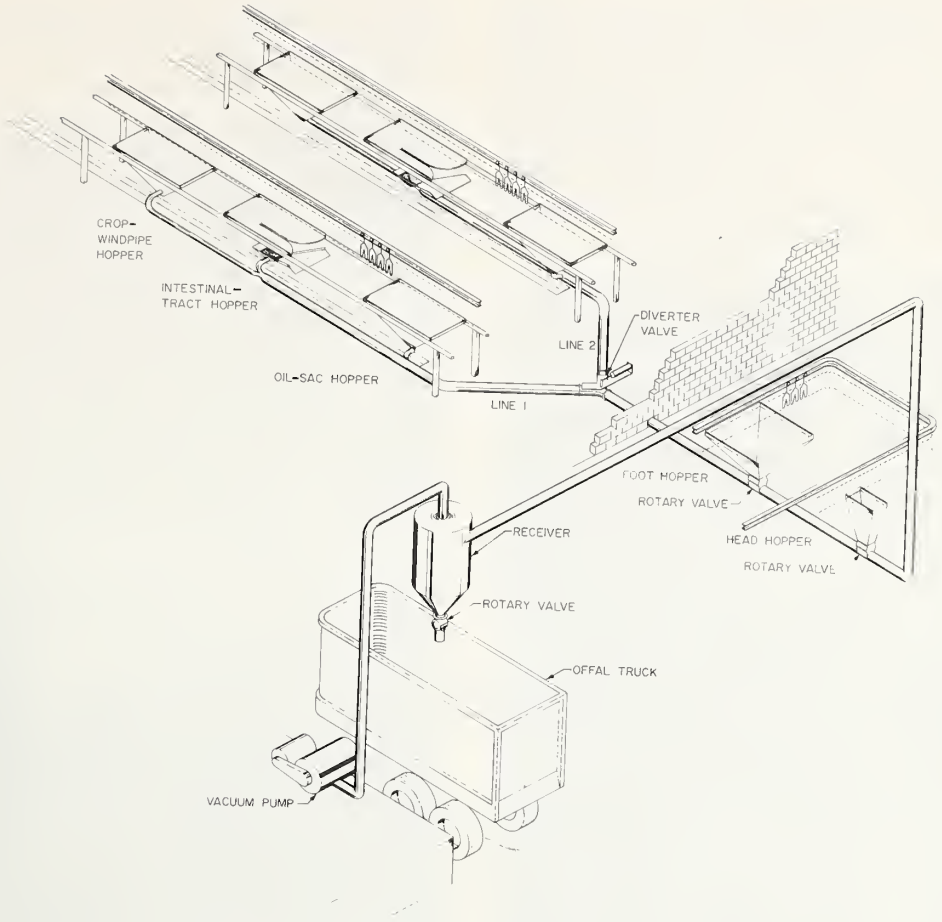

FIGURE 1.—Layout of pneumatic waste-handling system.

equipped with a 60-hp motor. The pump is a liquid-piston type with a vaned rotor turning in a cylindrical housing partly filled with water. About 20 gal/min of water are required for best pump performance.

Receiver.—The stainless-steel separator, or negative receiver, is 30 in o.d. by 65 in high with a capacity of about 20 ft^3 (figs. 2 and 3). The receiver has a 5-in-o.d. material inlet and a 6-in air outlet, a 6-in sight port, a high-level control-shutoff switch, and a sprayhead for washout. It was located on the roof of the plant directly above the offal truck so that the waste was continuously discharged into the truck. The pump and receiver are connected by a 6-in polyvinylchloride (PVC) pipe (fig. 1).

A rotary air-lock valve with a discharge capacity of 1.2 ft^3/r operating at 20 r/min was mounted onto the bottom of the separator to continuously discharge the collected waste. This valve was larger than necessary; one with a discharge capacity of about one-half this volume would probably be sufficient.

Head and foot hoppers.—A 5-in-o.d. aluminum tube extends horizontally along the roof about 152 ft from the separator to a right-angle elbow at a point above the head collection hopper. The tube continues vertically about 16 ft to the floor, through another right-angle elbow, and into a rotary valve placed underneath the head puller (fig. 4). This air-lock feeder valve has a capacity of 0.4 ft^3/r and operates at 17 r/min (a smaller capacity rotary valve could be used at this point). The heads from two defeathering lines were fed into the valve by a collection hopper mounted on top of the valve. The heads enter the airstream through a conveying transition device mounted on the bottom of the rotary valve (fig. 5).

The tube then extends along the floor about 25 ft to a foot receiving hopper equipped with

a second rotary valve (same capacity as the valve on the head collection hopper). This valve, located directly beneath the foot discharge mechanism for both defeathering lines, has a 46- by 46-in hopper mounted on the top (fig. 6). A conveying transition was mounted on the bottom to feed the feet into the conveying tube. The 5-in tube then passes through a wall and enters the eviscerating room (fig. 1).

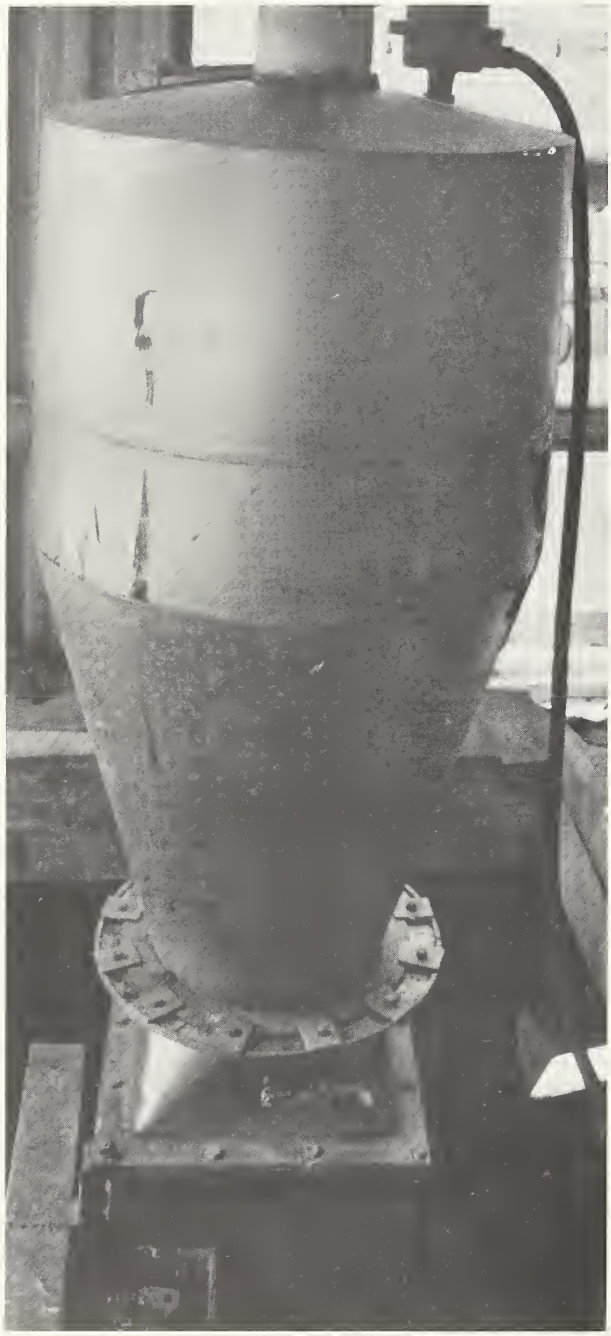

FIGURE 2.—Separator and discharge rotary valve.

Eviscerating room.—In the eviscerating room, the 5-in-o.d. tube extends along the floor and enters a diverter valve (fig. 7). The purpose of this valve is to switch the airstream alternately from one eviscerating line to the other. The valve is equipped with an air-operated cylinder and is actuated by a solenoid-controlled timer clock. Several intervals were tried, and a 20-second cycle proved to be best: the airstream flows through line 1 for 20 seconds, then is switched to line 2 for 20 seconds.

Two 4-in PVC pipes run from the diverter valve along the eviscerating room floor to the collection hoppers for oil sacs at the beginning of each eviscerating line. The oil-sac hoppers are connected directly to the 4-in pipe by a 2-in-o.d. plastic tube (fig. 8). These hoppers have a top opening 30 in wide by 60 in long and are 26 in deep (fig. 9). The bottom is 2.5 by 2.5 in with a 1.5-in-diameter orifice. Near the

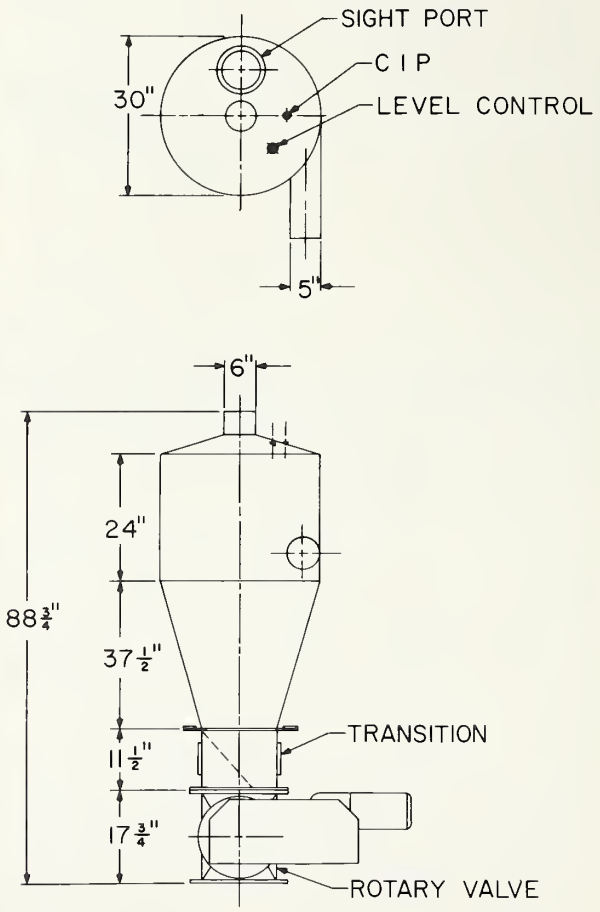

FIGURE 3.—Separator and discharge rotary-valve assembly.

bottom, the sides have slotted openings to allow flush water to drain. A 2-in-diameter hard-surfaced ball was drilled, tapped, and fitted with an eye screw to be used as a plug for the orifice. It was attached to the top of the hopper with a chain just long enough to reach the bottom of the hopper. This ball can be removed by pulling the chain when the hopper needs to be emptied. This simple device was used to increase the airflow through the two other hoppers on the line. Also, oil sacs do not accumulate fast enough to require that the hopper be emptied at 20-second intervals.

The 4-in PVC pipe continues along the floor about 30 ft to a Y-shaped manifold near the intestinal-tract hopper. A short length of 3-in flexible plastic tubing connects the intestinal-

FIGURE 4.—Collection hopper and rotary valve for heads.

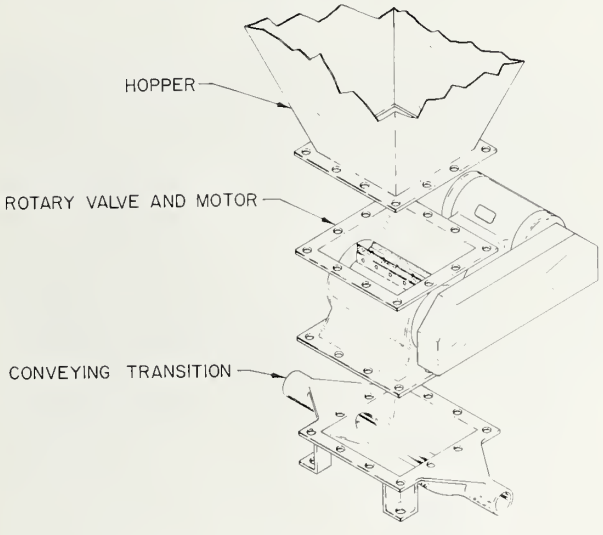

FIGURE 5.—Typical hopper, rotary valve, and conveying-transition arrangement.

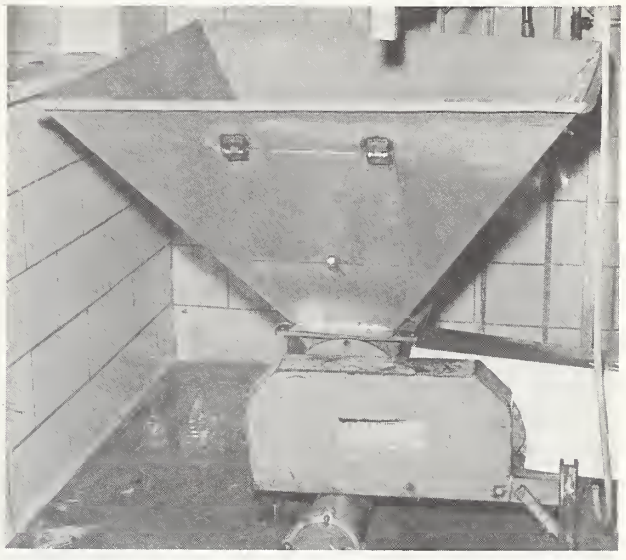

FIGURE 6.—Collection hopper and rotary valve for feet.

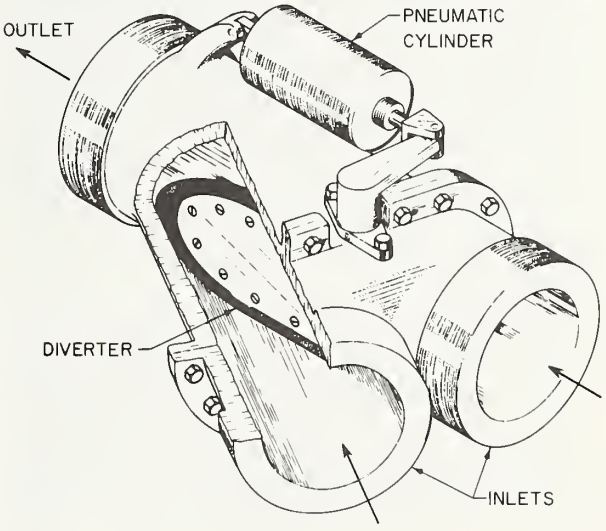

FIGURE 7.—Diverter valve used to switch airflow from eviscerating line 1 to line 2.

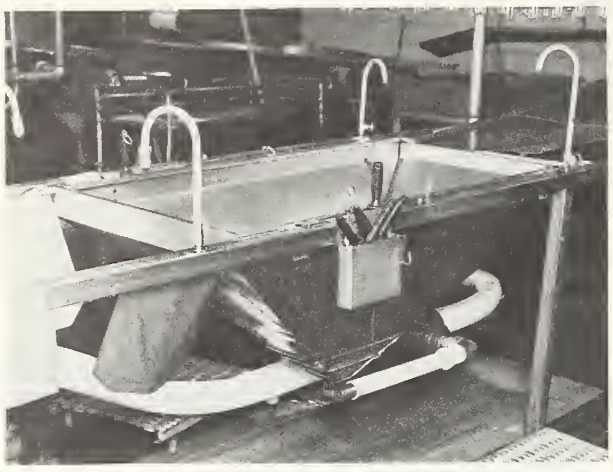

FIGURE 8.—Collection hopper for oil sacs.

tract hopper to this Y-shaped manifold. A 3-in PVC pipe extends from the manifold about 25 ft to the far end of the eviscerating line to the crop and windpipe hopper (fig. 1).

The first intestinal-tract hopper (fig. 10) was 72 in long by 30 in wide by 26 in deep. The bottom was 2.5 by 2.5 in, with a built-in grid made of slotted screen in the bottom and on three sides near the bottom to allow flush water to drain (fig. 11). The air line entered the side of the hopper and extended down inside the hopper, and the intestinal tracts were picked up through a 2.75- by 2.75-in opening. Some problems developed with this hopper design. Whole birds, large balls of paper towels, or other objects would stop up the evacuation orifice. Waste products would then accumulate rapidly in the hopper, and the congested work area made it difficult to clean the orifice without a shutdown of the processing line.

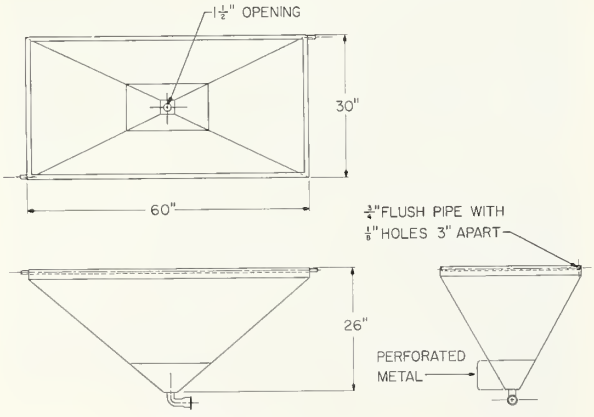

FIGURE 9.—Orthographic view of an oil-sac hopper.

A modified intestinal-tract hopper (fig. 12) was later installed. It was constructed in two pieces: the top section was 72 in long by 36 in wide, with a 1.5-in slot opening from the forward end to 6 in beyond the center of the bottom section. This slot was wide enough to allow the intestines to drop through but trapped the gizzards. This section was shallow, only about 5 in deep. The bottom section was suspended about 19 in below the bottom of the top section. This section had a top opening 30 in long by 13 in wide and was 9 in deep. It was positioned beneath the top section so that material passing through the slot would drop into the bottom section. The bottom and three sides were constructed of the slotted screen. A 2.75- by 2.75-in air line extended down the inside and

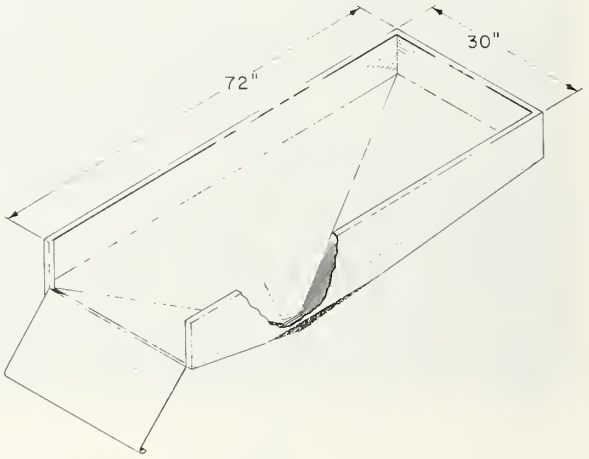

FIGURE 10.—Isometric view of an intestinal-tract hopper.

picked up the intestinal tracts from the bottom. Material that stopped up the air line was easily removed from this hopper.

The first crop and windpipe hopper had a top opening 30 in wide by 72 in long and was 26 in deep (fig. 13). The bottom was 2.5 by 2.5 in with a 2-in-diameter orifice. Waste material was pulled through this orifice into the 3-in PVC pipe. The bottom and lower part of the hopper sides were made of slotted screen to allow flush water to drain. This hopper was later modified so that the air line extended down the inside and picked up the material from the bottom similar to the intestinal tract hopper (fig 14).

The hoppers have built-in pipes for periodically flushing the sides with water. A 0.75-in-

o.d. tube is fastened underneath the lip on all four sides of the hopper. The tube has 0.125-in holes drilled on 3-in centers to flush the sides. The tube is connected to a main waterline, and water is controlled by a solenoid valve actuated by the timer clock that controls the diverter valve.

The troughs are flushed for about 4 or 5 seconds every 5 minutes. The timer is set so that the flush cycle begins on line 1 just as the vacuum is switched to line 2, and line 2 hoppers are flushed when the vacuum is diverted back to line 1. This allows about 15 seconds for the flush water to drain before the pickup cycle begins.

Warning system.—The warning system has three auxiliary contacts in the pump starter and two contacts in each of the discharge, feet,

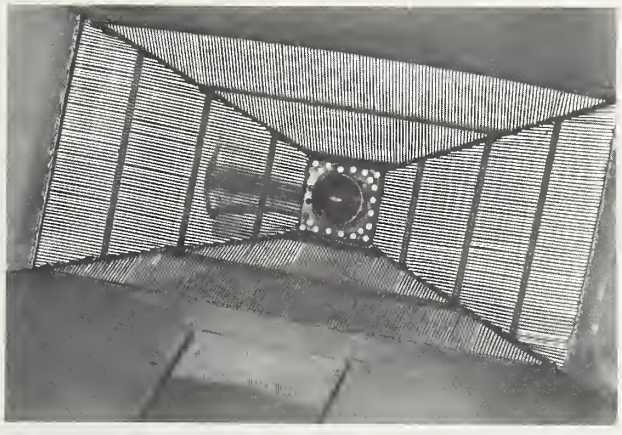

FIGURE 11.—Inside of an intestinal-tract hopper showing openings to allow flush water to drain.

and head valve-motor starters (fig. 15). A double-pole double-throw (DPDT) relay, a 10-second time-delay relay, a warning horn, a warning light, five pilot lights, and a high-level control in the receiver complete the system.

If the pump motor or any of the rotary airlock valve motors fail, the warning horn and light are activated, and the pilot light for the malfunctioning unit comes on in the maintenance area. If the pump stops, the circuit immediately stops the feet and head valves to prevent plugging the air duct. The high-level controls on the receiver will stop the pump and activate the warning light and horn and its pilot light in maintenance quarters, if the discharge rotary valve jams or breaks a drive chain.

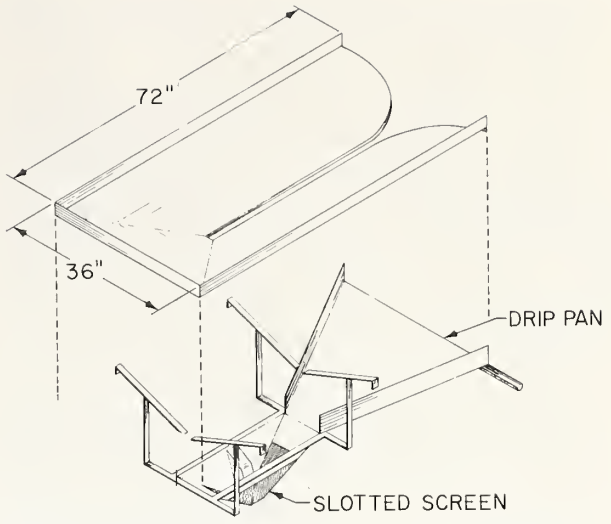

FIGURE 12.—Isometric view of a modified intestinal-tract hopper.

RESULTS

The experimental pneumatic waste-handling system has operated satisfactorily in a commercial processing plant for over 18 months. Some problems and equipment malfunctions have occurred, but the basic principle, design, and equipment have proven to be excellent. The system efficiently collects and transports the waste, reducing the materials discharged

FIGURE 13.—Collection hopper for crops and windpipes.

to the sewer and lowering the amount of potable water used.

This installation was designed so that as many variables as possible could be studied. However, since it was operated in a commercial plant, many of the design variables were fixed. Some equipment could not be modified because of the possibility of stopping the daily operation of the plant or because the expense would have been prohibitive. For instance, several rotary air-lock valves would be required to determine the proper size for each operation.

Conveying Tubes

An attempt was made to use 6-in PVC tubing from the receiver to the head and foot pickup stations. The air velocity in this tube was not sufficient to lift the waste material 16 ft vertically from the floor through the roof. The material collected in the vertical section of the tube and restricted airflow until the vacuum was increased. The increased vacuum would then lift all the material at once, slugging the receiver at a high impact. The replacement of the 6-in PVC tube with a 5-in aluminum tube corrected the problem.

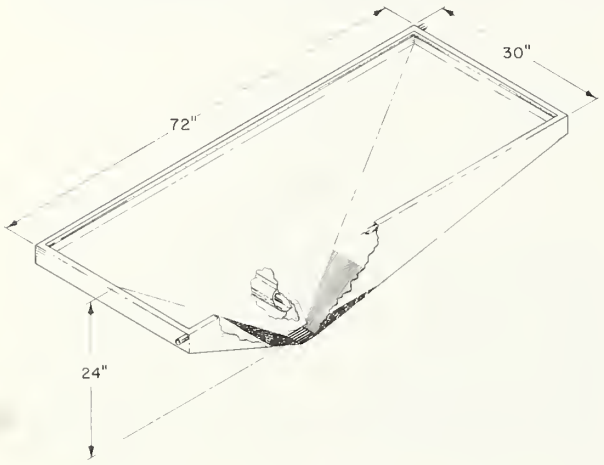

FIGURE 14.—Modified crop and windpipe hopper.

On several different days air velocity was measured in the 5-in aluminum tube with no waste material in the airstream. The measurements were made with a pitot tube and an inclined-tube manometer. The average air velocity varied from about 6,200 to 6,400 ft/min, corresponding to an average airflow rate of about 860 ft^3/min. About 25 to 30 ft^3/min were lost because of the discharge rotary valve on the receiver. The calculated air velocity in the 6-in pipe at 860 ft^3/min was less that 4,400 ft/min. Apparently an air velocity of 4,400 ft/min is too low to lift the material in the vertical section of the pipe, resulting in the slugging problem.

The 5-in aluminum tube was satisfactory for conveying the waste product for a rate of 9,600 birds/h. In fact, a 5-in aluminum tube can accomodate an even greater volume.

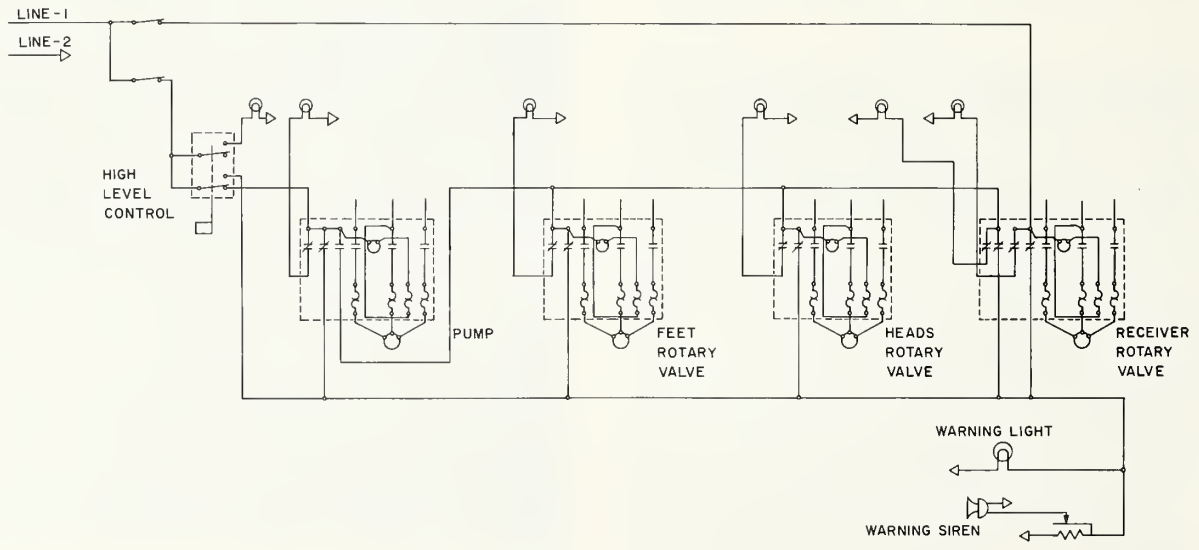

FIGURE 15.—Warning-system circuit.

Pollution Abatement

It was not possible to evaluate the pollution abatement resulting from pneumatically handling heads and feet, because heads previously were handcarted out of the plant and feet were flumed away with highly polluted recycled water. However, such effects were measured in the eviscerating area during a period when one eviscerating trough was operated in the conventional manner (with all waste material being dropped into the water) and the other in the experimental manner (with all waste being handled pneumatically without entering the water).

For these tests, waterflow was measured in both eviscerating troughs by means of a 90° V-notch weir and by collection in a container for timed intervals. The trough equipped with the pneumatic waste-handling system had a flow rate of 196 gal/min and the conventional trough 221 gal/min. These flows included the final washer and the gizzard splitters.

Water samples from each eviscerating trough were collected weekly for 3 weeks and analyzed for BOD_5, COD (chemical oxygen demand), suspended solids, and fat. Total organic carbon (TOC) samples were collected and analyzed daily. All analyses followed current water-pollution control standards (*1*). The total waste load was obtained from the waterflow and the concentration of the waste in the stream (table 1). The portion of the total waste contributed by the eviscerating room was 37% of the BOD_5, 42% of the COD, 33% of TOC, 32% of the suspended solids, and 97% of the fat.

The pneumatic waste-handling system reduced the pollution of the eviscerating effluent by: BOD_5, 75%; COD, 79%; TOC, 57%; suspended solids, 78%; and fat, 77%. Based on these figures, the pneumatic waste-handling system reduced the total plant discharge during the period of this test by: BOD_5, 28%; COD, 34%; TOC, 19%; suspended solids, 25%; and fat, 75%.

Water-Use Reduction

The pneumatic waste-handling system did not result in a direct savings in water. In fact, about 20 gal/min are required to operate the vacuum pump, and some water is required to flush the sides of the hoppers in the eviscerating room. Indirectly, however, water use was reduced, with most of the saving in the eviscerating area. Monthly water-meter readings were made to determine overall plant water use. For 6 months after the waste-handling system was completed, average plant water consumption for all uses was 8.70 gal/bird processed. For the same period a year earlier, water use was 11.26 gal/bird processed. The savings is 2.56 gal/bird processed, or a 23% reduction.

In addition to the waste-handling system, several factors caused this reduction. During the time the pneumatic equipment was installed, other water-saving changes were made. The final washers were modified; the gizzard splitters were replaced with new ones; the eviscerating troughs were removed and replaced by floor drains (including the replacement of much of the plumbing in the eviscerating room); some of the goose-neck hand-washing pipes were

TABLE 1.—*Comparative waste loads of two eviscerating troughs: a conventional system and a pneumatic waste-handling system*

[Pounds per 1,000 broilers processed]

Parameter	1st week		2d week		3d week	
	Conventional system	Pneumatic system	Conventional system	Pneumatic system	Conventional system	Pneumatic system
Biochemical oxygen demand (BOD_5)	47.4	18.6	54.2	10.2	50.0	8.7
Chemical oxygen demand (COD)	111.0	30.1	60.9	10.9	67.1	11.6
Total organic carbon (TOC)[1]	8.0	4.4	5.7	2.0	2.7	1.0
Suspended solids	28.1	7.5	15.3	3.2	20.8	4.0
Fat	74.2	7.1	9.5	4.8	46.2	3.8

[1] Values reported are averages for 5 days.

fitted with spray nozzles and some were eliminated. In addition, a 10-hp pump, used to recirculate water from the offal room to flow away the feet, was eliminated. Additional effort beyond the installation of the waste-handling system is required to reduce water use.

Maintenance

During the operation of the equipment several items were found to need special maintenance. The clearance on the tips of the vanes of the rotary air-lock valves must be maintained at the closest tolerance possible without scraping. When they are allowed to have too much clearance a large amount of air leaks through them, and they do not shear the material as they should. Improper shearing action, especially of feet, can jam or lock the rotors.

Special attention should be given daily to cleaning and flushing the air lines to maintain a sanitary condition. There was little buildup of material in the tubes. The cleaning water used on the hoppers was flushed through the system and was sufficient for cleaning them.

The diverter valve (figs. 1 and 7) is vital for proper waste collection in the eviscerating room. The air cylinder that operates the valve should be equipped with an air-pressure regulator, a speed regulator, an automatic oiler, and a water accumulator. The water accumulator should be fitted with a solenoid-actuated drain valve and set to open every 30 to 45 minutes with a clock timer, preventing it from filling and allowing water to enter and damage the air cylinder. The valve should be inspected monthly for damage or wear and the diverter properly adjusted to completely seal off each line.

LITERATURE CITED

(1) American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th ed, 874 pp. The Association, New York.

(2) American Society of Agricultural Engineers. 1974. Agricultural engineers yearbook. 620 pp. The Society, St. Joseph, Mich.

(3) Carawan, R. E. 1971. Proceedings: Workshop on poultry processing plant water utilization and waste control. Water Resources Research Institute, University of North Carolina, Rep. No. 59, 92 pp.

(4) Carawan, R. E., Crosswhite, W. M., Macon, J. A., and Hawkins, B. K. 1974. Water and waste management in poultry processing. U.S. Environ. Prot. Agency [Rep.] EPA–660/2-74–031, 223 pp.

(5) Jorgensen, R. 1970. Fan engineering. 729 pp. Buffalo Forge Co., Buffalo.

(6) Kerns, W. R., and Holemo, F. J. 1973. Cost of waste water pollution abatement in poultry processing and rendering plants in Georgia. Univ. Ga. Bull. ERC–0673, 39 pp.

(7) U.S. Department of Agriculture. 1973. Meat and poultry inspection manual. 314 pp.

(8) ———. 1974. Agricultural statistics 1973. 617 pp.

(9) Whitehead, W. K., Childs, R. E., Thomson, J. E., and Cox, N. A. 1973. A final bird washer: design, specifications, and evaluation. U.S. Dep. Agric., Agric. Res. Serv. [Rep.] ARS–S–27, 8 pp.

(10) Woodard, F. E., Sproul, O. J., Hall, M. W., and Ghosh, M. M. 1972. Abatement of pollution from a poultry processing plant. J. Water Pollut. Control Fed. 44: 1909–1915.

* 1976-G.P.O./1750-S/671-583/78